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DESCRIPTION

METHOD AND APPARATUS FOR PRODUCING MASK

Technical Field

The present invention relates to a producing method and a producing apparatus of a photomask used, for example, when micro devices such as semiconductor integrated circuits, image pickup devices (CCDs etc.), liquid crystal displays and thin film magnetic heads are produced using lithography technique.

Background Art

When a device such as a semiconductor integrated circuit is produced, a transferring method is employed in which, using a photomask on which a mask pattern (original pattern) obtained by enlarging, four to five times for example, a circuit pattern to be formed, an image of the mask pattern is reduced and projected onto a substrate to be exposed such as a wafer through a reduction projection optical system. An exposure apparatus is used in transferring such a pattern of the photomask. A photomask used in a step-and-repeat type reduction projection exposure apparatus is also called a reticle.

~~Conventionally, a reticle is produced in such a manner that a resist is applied on a predetermined substrate (mask blank) on which a light shield film is formed and then, a predetermined pattern is drawn using an electron beam drawing apparatus or a laser beam drawing apparatus and developed, thereby carrying out patterning of the resist, and the light shield film is etched using the remained resist pattern as a mask.~~

In recent years, as an integrated circuit is becoming finer, it is required to further comprehensively enhance a resolution of a transfer image from a reticle to a wafer. Therefore, in the reticle itself, engineering development has been made to transfer a fine pattern at a high resolution and as a result, a phase-shift reticle is proposed as a reticle capable of enhancing a resolution of a transfer image to a wafer in Japanese Patent Publication No.62-50811.

According to this phase-shift reticle, a phase shifter for deviating a phase of transmission illumination light by π (rad) is formed in correspondence with a predetermined light shield pattern on the reticle. In the phase-shift reticle, in a portion (transmission portion) other than the light shield pattern on the reticle, a width of a dark line at a boundary between a portion where the phase shifter is not formed i.e., a reference region where a phase of transmitted

light is not varied, and a portion where the phase shifter ~~is formed, i.e., a region~~ where the phase of transmitted light is deviated with respect to the transmitted light in the reference region by π (rad) is minimized by cancellation effect by interference of light, thereby enhancing the resolution. Therefore, if the phase shifter is formed such that the boundary coincides with the light shield pattern, the light shield pattern can be transferred at a high resolution.

However, in the case of the phase-shift reticle, there is a problem that the region where the phase shifter is formed consequentially becomes a closed region, and a boundary is also formed in a portion other than the desired region based on the design data of the circuit pattern, to adversely form an unnecessary dark line. As a method for removing the unnecessary dark line, Japanese Patent Application Laid-open No. 4-76551, for example, proposes a method in which exposure is carried out using a phase-shift reticle and then, ~~superimposing~~ exposure is carried out ~~using another reticle~~ on which a pattern for removing (exposing) the unnecessary dark line is drawn.

As described above, conventionally, in order to remove the unnecessary dark line generated by using the phase-shift reticle, a correction exposure reticle on which a

predetermined pattern is drawn is formed, and after the pattern is transferred at a high resolution using the phase-shift reticle, a superimposing exposure is carried out using the correction exposure reticle.

Further, conventionally, when the phase-shift reticle and the correction exposure reticle are produced, two kinds of patterns for both the reticles are designed, and these patterns are respectively drawn on predetermined substrates separately. However, with this method for separately designing and drawing the two kinds of patterns, there is inconvenience that a time required for producing the two reticles is long, and the producing costs of the reticles and by extension the producing costs of devices are increased.

Further, even if the resolution at the time of reduction projection is enhanced, if the precision of a mask pattern on the reticle is low, there is an adverse possibility that necessary precision of the line width and the like can not be obtained. Therefore, it is required to form a fine mask pattern on a substrate with high positional precision at a high resolution with high line width uniformity.

In view of the above circumstances, it is a first object of the present invention to provide a producing method of a mask capable of producing a phase-shift reticle and a correction exposure reticle within a short time at low cost.

Further, it is a second object of the invention to provide a producing method of a mask capable of producing a phase-shift reticle and a correction exposure reticle with high precision.

Further, it is a third object of the invention to provide a producing method of a mask capable of producing a correction exposure reticle within a short time at low cost.

Further, it is a fourth object of the invention to provide a producing apparatus of a mask capable of carrying out the above mask producing method, and to provide a mask produced using the mask producing method. Further, it is still another object of the present invention to provide a producing method of a device using the above mask producing method.

Disclosure of the Invention

Ins B1

A first producing method of a mask of the present invention is a producing method of a mask for producing a phase-shift mask (WR1) and a correction exposure mask (WR2) used when a transmission image of a pattern of the phase-shift mask is corrected by superposing exposure, wherein a parent pattern (PA1 to PC1) is formed on a first substrate to form a master mask (MR), the parent pattern of the master mask is transferred onto a second substrate under a first

condition, and a predetermined phase shift portion (SA to SD) is formed on the second substrate, thereby forming the phase-shift mask (WR1), and the parent pattern of the master mask is transferred onto a third substrate under a second condition which is different from the first condition, thereby forming the correction exposure mask (WR2).

According to the mask producing method of the present invention, when a light shield film, for example, is formed on the third substrate and a positive photoresist is applied on the film, the second condition is set such that an amount of exposure is smaller than that in the first condition. If the parent pattern of the master mask is transferred under the second condition, and development, etching and the like are carried out, a pattern having thicker line width than that of a pattern formed under the first condition, i.e., than that of a pattern of the phase-shift mask is formed. Therefore, if the pattern of the phase-shift mask is a fine periodic pattern, the pattern having a thick line width is a pattern covering the entire periodic pattern and thus, this mask can be used as the correction exposure mask.

In this case, even if the second condition is set such that the resolution at the time of transfer is lower (the numerical aperture of a projection optical system is made smaller) than that in the first condition, since the transfer

pattern is enlarged, the same effect can be obtained.

When the parent pattern of the master mask is transferred under the second condition, it is preferable to defocus the third substrate with respect to an image plane of the projection optical system.

Further, when the parent pattern is formed to produce the master mask, an electron beam drawing apparatus can be used for example, and when the parent pattern of the master mask is transferred to produce the phase-shift mask and the correction exposure mask, an optical projection exposure apparatus can be used for example. Therefore, as compared with a method in which two kinds of patterns are designed for the phase-shift mask and the correction exposure mask and these patterns are drawn using an electron beam drawing apparatus, a pattern designing time and a using time of the electron beam drawing apparatus are largely shortened and thus, it is possible to produce both the masks within a short time and at low cost. Especially when a plurality of sets of both the masks are produced, according to the present invention, it is only necessary to repeatedly transfer the pattern of the master mask and thus, a time and a cost required for producing the masks are largely reduced.

At that time, it is preferable that the parent pattern is divided into a plurality of partial parent patterns to form

a plurality of master masks, and the partial parent patterns of the master masks are transferred while stitching screens with a reduced magnification of $1/\alpha$ ($1/\alpha$ is 1/4, 1/5 or the like for example). With this arrangement, since a drawing error due to the electron beam drawing apparatus is also reduced to $1/\alpha$, it is possible to enhance the line width control precision, the positional precision and the like of the patterns of both the phase-shift mask and the correction exposure mask.

B2

~~Next, a second~~ producing method of a mask of the present invention is a producing method of a mask for producing a correction exposure mask (WR2) used when a transfer image of a pattern of a predetermined phase-shift mask is corrected by superimposing exposure, wherein a parent pattern is formed on a first substrate (R) to produce a master mask (MR), the parent pattern of the master mask is transferred onto a second substrate (R2) under a condition (e.g., condition of a lower resolution) different from a condition under which a light shield pattern of the phase-shift mask is formed, thereby forming the correction exposure mask. With this mask producing method, it is possible to produce the correction exposure mask within ~~a short time and at low cost.~~

It is preferable that the condition includes at least one of an exposure amount, a resolution, and focus.

Sub B3

Next, a producing apparatus of a mask of the present invention is a producing apparatus of a mask for producing a plurality kinds of masks different from one another, comprising a mask stage (13) which holds a master mask (MR) on which a parent pattern is formed, a substrate stage (8, 9) which sequentially holds and positions a plurality of mask substrates (R1, R2) for the masks, illumination optical systems (1 to 5) which illuminates the master masks on the mask stage, a projection optical system (PL) which transfers an image of the parent pattern of the master mask onto the mask substrate on the substrate stage, and a control system (16) which adjusts at least one of an exposure amount with respect to the mask substrate and a resolution of the projection optical system in accordance with kinds of the mask to be produced. According to this mask producing apparatus of the present invention, it is possible to carry out the mask ~~producing methods of the present invention.~~

Sub B4

Next, a first producing method of a device of the present invention is a method for producing a predetermined device, comprising: a first step of drawing a parent pattern corresponding to a pattern of a predetermined layer of the device onto one or a plurality of first substrates to form a master mask (MRi, Mpi),

a second step of transferring the parent pattern of the

master mask onto a second substrate under a first condition and forming a predetermined phase-shift portion on the second substrate, thereby forming a phase-shift mask (WR1), a third step of transferring the parent pattern of the master mask onto a third substrate under a second condition which is different from the first condition, thereby forming a correction exposure mask (WR2), and a fourth step of exposing in a superimposing manner the pattern of the phase-shift mask and the pattern of the correction exposure mask on a fourth substrate (W).

According to this present invention, since it is possible to produce the phase-shift mask and the correction exposure mask with high precision within a short time, a time required for producing the device can be shortened, and an advanced device having a fine pattern can be produced at low cost.

The first and second masks of the invention are produced using the mask producing methods and the mask producing apparatus of the present invention, respectively, and there is a merit that the phase-shift mask and the correction exposure mask can be obtained within a short time at low cost. The second producing method of a device of the present invention includes the step for transferring the device pattern onto the device substrate using the mask of the present

invention, and an advanced device having a fine pattern can be produced at lower cost.

Ins B28

Brief Description of the Figures in the Drawings

Sub B3

Fig.1(A) is a plan view ~~showing a master~~ reticle MR used in one example of a preferred embodiment of the present invention, Fig.1(B) is a plan view showing a substrate R1 on which light shield patterns PA2, PB2 are formed, Fig.1(C) is a plan view showing a phase-shift reticle WR1, and Fig.1(D) is a plan view showing a correction exposure reticle WR2. Fig.2 is a view for explaining an exposure condition when the phase-shift reticle WR1 and the correction exposure reticle WR2 are produced. Fig.3 is a schematic constitutional view showing an optical projection exposure apparatus for producing a reticle used in the one example of the preferred embodiment of the present invention. Fig.4 is an explanatory view of steps of producing a set of master reticles from a predetermined circuit pattern in the preferred embociment. Fig.5 is an explanatory view of steps of producing a semiconductor device using the set of ~~master reticles~~.

Best Mode for Carrying out the Invention

One example of a preferred embodiment of the present invention will be explained with reference to the drawings

below. In this example, the present invention is applied for producing a phase-shift reticle and a correction exposure reticle for producing a semiconductor device.

Ins B1e

Fig.1(A) shows a master reticle MR used for producing the phase-shift reticle and the correction exposure reticle of the present example using an optical projection exposure apparatus. In Fig.1(A), the master reticle MR is formed with a parent pattern PA1 of a dense pattern comprising light shield patterns P1 to P3, and T-shaped parent patterns PB1 and PC1 comprising isolated light shield patterns. These parent patterns PA1 to PC1 are obtained by enlarging, in a similarity manner, circuit patterns of a certain layer of a semiconductor device which is to be finally produced. Each the parent pattern has a size of $\alpha \cdot \beta$ times enlarged circuit pattern of the semiconductor device to be finally produced if a reduction magnification of a projection exposure apparatus for producing a semiconductor device is defined as $1/\beta$ ($1/\beta$ is 1/4, 1/5 or the like for example) and a reduction magnification of a projection exposure apparatus for producing a reticle is defined as $1/\alpha$ ($1/\alpha$ is 1/4, 1/5 or the like for example). Alignment marks 22A and 22B comprising two two-dimensional marks are formed on the master reticle MR with a predetermined positional relation with respect to the parent patterns PA1 to PC1.

Sub B2

~~Although the parent patterns PA1 to PC1 are illustrated in Figs.1 and 2 with thick line width for the sake of convenience, the actual pattern has a line width of on the order of μm. Patterns in Figs.1(B) to (D) are, for example, reversed and reduced with respect to the pattern shown in Fig.1(A), but these patterns are illustrated in a normal state with equal magnification for the sake of convenience.~~

When the master reticle MR is produced, a thin film as a mask material such as chromium (Cr) or molybdenum silicide ($MoSi_2$ or the like) is formed on a light transmission substrate R made of silica glass (SiO_2), silica glass doped with fluorine, fluorite and the like, an electron beam resist is applied on the thin film and then, an equal-magnification image of patterns corresponding to the parent patterns PA1 to PC1 are drawn using an electron beam drawing apparatus. Next, the electron beam resist is developed and then, etching and resist removing operations are carried out, thereby forming the parent patterns PA1 to PC1 on the substrate R. A laser beam drawing apparatus can be used instead of the electron beam drawing apparatus.

In this example, the parent patterns PA1 to PC1 of this master reticle MR are transferred onto the reticle substrate with reduced magnification $1/\alpha$ using an optical projection exposure apparatus which will be described later, thereby

producing the phase-shift reticle and the correction exposure reticle. Therefore, the drawing error by the electron beam drawing apparatus is reduced to $1/\alpha$, and patterns of the phase-shift reticle and the correction exposure reticle can be formed precisely. In this case, practically, an enlarged pattern of a circuit pattern formed on a wafer is divided into N-number of parent patterns (N is an integer equal to 2 or greater), and the parent patterns are drawn on different substrates to form N-number of master reticles. Reduced images of the parent patterns of the N-number of master reticles are sequentially transferred onto the substrates while stitching screens, thereby producing the phase-shift reticle and the correction exposure reticle. The number of divided patterns may not be the same as that of the master masks. For example, a plurality of divided patterns (partial parent patterns) may be formed on one master mask.

Fig.1(B) shows a light transmission substrate R1 made of silica glass, silica glass doped with fluorine, or fluorite. In Fig.1(B), light shield patterns PA2 to PC2 on the substrate R1 are formed by transferring the parent patterns PA1 to PC1 of the master reticle MR with reduced magnification of $1/\alpha$. The substrate R1 made of magnesium fluoride, predetermined quartz crystal or the like may also be used. The light shield patterns PA2, PB2, PC2 are equal to β times enlarged circuit

pattern of a semiconductor device to be finally produced. On the substrate R1, alignment marks 23A and 23B comprising two two-dimensional marks are previously formed for positioning operation when superimposing exposure is carried out. The patterns for the alignment marks 23A and 23B may be formed on a portion of the parent pattern, and the alignment marks 23A and 23B may be formed at the same time when the light shield patterns PA2 to PC2 are formed.

When the light shield patterns PA2 to PC2 are formed on the substrate R1, a light shield film made of chromium, molybdenum silicide or the like is formed on a pattern region on a surface of the substrate R1, and positive photoresist is applied on the film. Then, images of the parent patterns PA1 to PC1 of the master reticle MR are transferred at reduced magnification of $1/\alpha$ using the optical projection exposure apparatus. At that time, in order to form the reduced images of the parent patterns PA1 to PC1 on the substrate R1 with high precision, the projection exposure is carried out with an appropriate amount of exposure light using the optical projection exposure apparatus having sufficient resolution. In this example, a positive resist having photosensitive portion which can be melted is used as the photoresist. The images of the parent patterns PA1 to PC1 are used as light shield portions. When a negative photoresist having

photosensitive portion which remains is used, a transmission portion and a light shield portion are reversed as compared with the positive photoresist. Therefore, in order to form the images of the parent patterns PA1 to PC1 as the light shield portions, it is necessary to use a master reticle whose transmission portion and light shield portion are reversed in Fig.1(A).

B10

~~The photoresist~~ is developed and then, ~~the etching and~~ resist removing operations are carried out, and the light shield patterns PA2 to PC2 are formed on the substrate R1. After the light shield patterns PA2 to PC2 are formed on the substrate R1, the phase shifter is further formed, thereby producing the phase-shift reticle shown in Fig.1(C).

B11

In Fig.1(C), the phase-shift reticle WR1 comprises a substrate R1 on which the light shield patterns PA2 to PC2 are formed and phase shifters SA to SD formed on the substrate R1 and having light transmission phases deviated by π (rad). By forming the phase shifters SA to SD, a width of a dark line on a boundary between a region (region where neither light shield pattern nor phase shifter is formed) where a light transmission phase is not affected on the phase-shift reticle WR1, and a region (region where the phase shifter is formed) where the light transmission phase is shifted by π (rad) is minimized by compensating effect caused by interference of

~~light. Thus, it is possible to transfer a pattern while enhancing the resolution of the dark line on the boundary portion. Therefore, the phase shifters SA to SD are respectively formed along one of edges of the corresponding light shield pattern PA2 in the longitudinal direction and along one of edges of the linear portions of the T-shaped light shield patterns PB2 and PC2 in the longitudinal direction. Like the light shield pattern PA2 (dense pattern) comprising the light shield patterns PA21 to PA23, when a distance between the light shield patterns is narrow, it is only necessary to dispose one phase shifter with respect to the two light shield patterns PA21 and PA22 like the phase shifter SA.~~

When the phase shifters SA to SD are formed, a predetermined resist (photoresist or electron beam resist) is applied on a surface of the substrate R1 on which the light shield patterns PA2 to PC2 are formed and then, the substrate R1 is exposed such that the resist on a portion thereof where the phase shifter is formed is removed. Then, after the resist was developed, the substrate R1 is etched using the remained resist pattern and light shield patterns PA2 to PC2 themselves as etching masks. With this operation, portions which were etched through predetermined depth become the phase shifters SA to SD. Instead of etching the substrate to obtain the phase shifter, the substrate may be coated with a phase

member having a predetermined index of refraction.

The patterning of the resist on the phase shifter forming portion may be carried out using the electron beam drawing apparatus, but unlike the case in which the patterning is carried out with respect to a thin film made of chrome or the like, since there is no conductive layer covering the entire surface of the substrate R1, there is an adverse possibility that the drawing positional precision is lowered by local charge up. For this reason, it is preferable to use an optical projection exposure apparatus to carry out the patterning. In this case, portions where the phase shifters SA to SD are formed are patterned and drawn to prepare a master reticle for forming the phase shifter, and an image of that pattern is transferred by the optical projection exposure apparatus.

If reduced images of the phase-shift patterns PA2 to PC2 are transferred onto a semiconductor device-producing wafer or the like using the phase-shift reticle WR1 as a first working reticle, it is possible to form patterns of the reduced light shield patterns PA2 to PC2 at high resolution. However, as described above, in addition to the images of the light shield patterns PA2 to PC2 which are patterns to be transferred, images of boundaries (e.g., boundaries C1 and C2) between the phase shifters SA to SD and the transmission region are also

transferred as unnecessary dark lines.

Ins B12 ~~Thereupon, in the~~ present example, a correction exposure reticle WR2 is formed. On the correction exposure reticle WR2, light shield patterns PA3 to PC3 which are patterns having thicker line widths of the light shield patterns PA2 to PC2 of the phase-shift reticle WR1 shown in Fig.1(D) are formed. The light shield patterns PA3 to PC3 are formed in the same manner as that of the phase-shift patterns PA2 to PC2 of the phase-shift reticle WR1. That is, the light shield patterns PA3 to PC3 are formed in such a manner that reduced images of the parent patterns PA1 to PC1 of the master reticle MR are transferred onto a substrate R2 (material of the substrate R2 is the same as that of the substrate R1) formed with a light shield film on which positive photoresist is applied using an optical projection exposure apparatus. However, in this case, patterns having line widths thicker than those of the light shield patterns PA2 to PC2 by carrying out the exposure under a condition of exposure amount smaller (about half for example) than that required for forming the light shield patterns PA2 to PC2. ~~Therefore, the light shield pattern PA3 is formed as a pattern~~ in which the entire inside and periphery of the light shield pattern PA2 which is the dense pattern are formed as light shield portions. Further, like the phase-shift reticle WR1,

the correction exposure reticle WR2 is also formed with alignment marks 24A and 24B comprising two two-dimensional marks with a predetermined positional relation with respect to the light shield patterns PA3 to PC3.

At that time, when the alignment marks 24A and 24B are formed by transferring predetermined pattern like the light shield patterns PA3 to PC3, in order to prevent the resolution of the alignment marks 24A and 24B from being lowered, the alignment marks 24A and 24B are exposed at higher resolution in another exposing step different from those of the light shield patterns PA3 to PC3.

The correction exposure reticle WR2 of this example can also be called "normal reticle" with respect to the phase-shift reticle. In the correction exposure reticle WR2 as the second working reticle, portions (straight lines D1, D2 and the like) thereof corresponding to portions (boundaries C1, C2 and the like) forming the unnecessary dark lines of the phase-shift reticle WR1 are transmission regions. Therefore, the unnecessary dark lines are exposed by exposing in a superimposing manner (double exposing) the phase-shift reticle WR1 and the correction exposure reticle WR2. Therefore, the unnecessary dark lines generated by using the phase-shift reticle WR1 can be removed (exposed). At that time, since the light shield patterns PA3 to PC3 of the

correction exposure reticle WR2 are slightly greater than the light shield patterns PA2 to PC2 of the phase-shift reticle WR1, even if a superimposing error is generated in some degree at the time of exposing in a superimposing manner, there are merits that the unnecessary dark lines can reliably be removed, and the reduced images of the light shield patterns PA2 to PC2 are not affected.

Sub B13

~~A light~~ shield band 50 surrounding the light shield patterns PA2 to PC2 of the phase-shift reticle WR1 in Fig.1(C) is a frame-like light shield pattern having a predetermined width like the light shield pattern PA21 and the like. One edge of the phase-shift SD in the longitudinal direction closer to the light shield band 50 is extended to the light shield band 50. With this design, the above-described boundary does not exists on the edge of the phase shifter SD, the unnecessary dark line pattern is not transferred. Thus, in the case of the other phase shifters SA to SC also, if the edges are close to the light shield band 50, ends thereof may be disposed in the light shield band 50 to reduce the boundaries.

Sub B14

Next, exposure conditions when the phase-shift reticle WR1 and the correction exposure reticle WR2 of this example are produced will be explained with reference to Fig.2.

Sub B15

Fig.2(A) is an enlarged sectional view of the master

reticle MR shown in Fig.1(A) taken along a lint A-A. In Fig.2(A), parent patterns PA1 (light shield patterns P1 to P3) and PB1 comprising light shield pattern are formed on a reticle substrate R. In the following explanation, a short side direction of each of the light shield patterns P1 to P3 ~~and the reduced images thereof is defined as an X-direction.~~

B16 Fig.2(B) shows intensity of light on the substrate R1 when the light shield patterns PA2 and PB2 are formed on the substrate R1 shown in Fig.1(B). In Fig.2(B), the horizontal axis indicates a position x in the X-direction, and the vertical axis indicates the intensity of light IM on the substrate R1 at the position x. An exposure amount Eth shown with a dotted line is an exposure amount required for melting the positive photoresist. A slice width of a light intensity distribution curve Imb with the exposure amount Eth corresponds to a line width of a pattern to be formed on the substrate R1. When the light shield patterns PA2 and PB2 are formed on the substrate R1, the exposure light amount is set to an appropriate exposure light amount, and images of the light shield patterns P1 to P3 and the parent pattern PB1 are formed using line widths X1 to X4, respectively (see Fig.1(B)).

B17 Fig.2(C) shows the light intensity on the substrate R2 when the light shield patterns PA3 and PB3 are formed on the substrate R2

substrate R2 shown in Fig.1(D). Fig.2(C) shows the light intensity Im in the position x in the X-direction of the substrate R2. The slice width of a light intensity distribution curve Imc with the exposure amount Eth corresponds to a line width of a pattern formed on the substrate R2. As an exposure condition at that time, the exposure amount is set to about a half of an exposure amount (appropriate exposure amount) when the light shield patterns PA2 and PB2 of the phase-shift reticle WR1 are formed. If images of the parent patterns PA1 and PB1 of the master reticle MR are transferred and developed under such a condition, since the resolution of images of the light shield patterns P1 to P3 which are dense line and space patterns is low, one light shield pattern PA3 (see Fig.1(D)) having a wide width X5 is formed. If an image of the T-shaped parent pattern PB1 which is an isolated pattern is transferred, a light shield pattern PB3 of line width X6 having a thick linear portion is formed. The line width X6 of this light shield pattern PB3 is thicker than the line width X4 of the light shield pattern PB2, and the width X5 of the light shield pattern PA3 in the X-direction is longer than a distance as measured from a left end of the image of the light shield pattern P1 formed on the substrate R1 to a right end of the image of the light shield pattern P3.

Here, when the light shield pattern of the correction exposure reticle WR2 is formed, the exposure amount is set smaller than the appropriate exposure amount, and the line width of the pattern to be formed is thickened. Alternatively, the light shield pattern of the correction exposure reticle WR2 may be formed using a projection exposure apparatus having a projection optical system of low resolution. In generally, the resolution of the projection optical system is proportional to a value (=λ/NA) of ratio of an exposure light wavelength λ to the numerical aperture NA. Therefore, when the light shield patterns PA3 and PB3 of the correction exposure reticle WR2 are formed, a projection optical system having smaller numerical aperture is used to carry out the exposure, thereby throwing the projected image out of focus. Different optical projection exposure apparatuses may be used for the phase-shift reticle WR1 and the correction exposure reticle WR2, or the same projection exposure apparatus in which a variable aperture stop is disposed on or in the vicinity of a pupil plane of the projection optical system may be used. Especially in the latter case, when the light shield pattern of the correction exposure reticle WR2 is formed, the numerical aperture of the projection optical system is reduced depending upon the variable aperture stop.

Sub B4 ~~Fig. 2(D) shows the light intensity on the substrate R2~~

~~when the light shield patterns PA1 and PB1 are formed using a projection exposure apparatus having a projection optical system of low resolution. Fig.2(D) shows the light intensity Im in the position x in the X-direction of the substrate R2. The slice widths X7 and X8 of a light intensity distribution curve Imd are respectively equal to the slice widths X5 and X6 of the light intensity distribution curve Imc at the exposure amount Eth in Fig.2(C). Using the projection exposure apparatus having the projection optical system of low resolution also, it is also possible to produce the correction exposure reticle WR2. When the parent pattern is transferred, it is also possible to bring the surface of the substrate R2 out from the best focus position of the projection optical system to throw the image out of focus. Further, these methods and a method for exposing with an exposure amount smaller than the appropriate exposure amount may be combined.~~

Assuming that the resists applied on both the reticles WR1 and WR2 are positive resists, the exposure amount when the image of the pattern of the master reticle MR is exposed on the correction exposure reticle WR2 is set smaller than the exposure amount for the phase-shift reticle WR1. Thus, if the resists applied on both the reticles WR1 and WR2 are negative resists, it is preferable to set the exposure amount for the correction exposure reticle WR2 greater than the

exposure amount for the phase-shift reticle WR1.

When the correction exposure reticle WR2 is produced, it is possible to control a line width of a pattern to be formed on a substrate not only by carrying out one of the exposure amount control, the defocus control and the resolution (the numerical aperture) control, but also by carrying out two or more controls in combination.

B19 ~~In this example, the phase-shift reticle WR1 shown in Fig.1(C) and the correction exposure reticle WR2 shown in Fig.1(D) are produced by transferring the reduced images of patterns of the master reticle MR shown in Fig.1(A) onto the substrates respectively. One example of an optical projection exposure apparatus for producing reticles which can be used at that time will be explained with reference to Fig.3.~~

Fig.3 shows an optical projection exposure apparatus for producing a reticle of this example. In Fig.3, exposure light (exposure light) IL emitted from an exposure light source 1 illuminates an aperture stop ("σ stop", hereinafter) 4 of an illumination system through a relay lens 2 and an optical integrator (fly-eye lens in Fig.3) 3. A size of the aperture of the σ stop 4 can be adjusted by a driving system 4a. An illumination optical system control apparatus 18 controls the light emission of the exposure light source 1

and a diameter of aperture of the σ stop 4 under control of a main control system 16 which has control over the operation of the entire apparatus. As the exposure light IL, it is possible to use excimer laser light such as KrF excimer laser light (wavelength is 248 nm) and ArF excimer laser light (wavelength is 193 nm), F_2 laser light (wavelength is 157 nm), high harmonic of YAG laser or i-line of mercury lamp (wavelength is 365 nm).

A portion of the illumination light IL passing through the σ stop 4 is reflected by the beam splitter 6 and then, enters into an integrator sensor 21 comprising an optoelectronic detector through a light-gathering lens 20. A detection signal of the integrator sensor 21 is supplied to the illumination optical system control apparatus 18. The illumination optical system control apparatus 18 indirectly monitors illumination (pulse energy) on a surface of the substrate R1 of the exposure light IL and an accumulated exposure amount at each point on the substrate R1 by the detection signal. The illumination optical system control apparatus 18 controls the light emitting time of the exposure light source 1 and attenuation ratio of the exposure light IL by a light amount attenuator (not show) such that the accumulated exposure amount to be monitored or the illumination becomes equal to a value instructed by the main

control system 16. If the exposure light source 1 is a pulse light source such as an excimer laser, the light emitting time is the number of light emitting pulses. To control the light amount (pulse energy in the case of the pulse light source) of the exposure light IL, the control of an output (such as voltage) of the exposure light source may be carried out in addition to the control of the light amount attenuator, or the light amount may be controlled only by controlling the output of the exposure light source. In the case of a full field exposure type projection exposure apparatus as in the present example, it is possible to directly control the accumulated exposure light amount.

On the other hand, in the case of a scanning exposure type projection exposure apparatus, in order to control the accumulated exposure light amount, the illumination of the exposure light IL, a width (defined by a field stop) in the scanning direction of the illumination region of the exposure light IL on the substrate R1 (R2), the scanning speed of a wafer and the like are controlled. When the exposure light source 1 is the pulse light source, an oscillation frequency may be controlled and illumination energy and by extension the accumulated exposure light amount per unit time may be controlled.

Ins B20

The exposure light IL passing through the beam splitter

6 illuminates the master reticle MR to be transferred through the condenser lens system 5. A pattern surface (lower surface) of the master reticle MR is formed with the parent patterns PA1 to PC1 shown in Fig.1(A) and the alignment marks 22A and 22B. The exposure light IL which has passed through the master mask MR forms an image obtained by reducing the parent pattern with reduction magnification of $1/\alpha$ ($1/\alpha$ is 1/4, 1/5 or the like) on the substrate R1 (or R2) which is for producing the reticle through the projection optical system PL. A variable aperture stop 7 is disposed on or in the vicinity of an optical Fourier-transform plane (pupil plane) with respect to a pattern forming surface of the master mask MR in a projection optical system PL, and the numerical aperture NA of the projection optical system PL is defined by the aperture stop 7. Although the condenser lens system 5 is illustrated briefly in the drawing, the actual condenser lens system 5 is an optical system in which an image is once formed therein and which has a reticle blind (field stop) on its image-forming surface (conjugate surface with the pattern ~~surface of the master reticle MR).~~

Like a common projection exposure apparatus, a resolution R of the projection exposure apparatus of this example is expressed as in the following equation using an exposure wavelength λ, a process coefficient k and a numerical

aperture NA on the emission side of the projection optical system PL:

$$R=k\times\lambda/NA$$

In this example, it is possible to adjust the numerical aperture NA and by extension the resolution R to desired values by adjusting the size of the aperture of the aperture stop 7 by the main control system 16 through a driving system 7a. The following explanation is based on a definition that a Z axis is in parallel with an optical axis AX of the projection optical system PL, an X axis is in parallel with a paper sheet of Fig.3 in a plane perpendicular to the Z axis, and a Y axis is perpendicular to the paper sheet of Fig.3.

First, the master mask MR is held on a reticle stage 13, the reticle stage 13 positions the master mask MR on a reticle base 14 within a predetermined range in X, Y and rotational directions. The position of the reticle stage 13 (master mask MR) is precisely measured by a laser interferometer incorporated in a reticle stage driving system 15, and the reticle stage driving system 15 controls a position of the reticle stage 13 based on the position information and control information from a main control system 16.

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Reticle alignment microscopes ("RA microscopes" hereinafter) 19A and 19B are disposed above the master mask MR. The positional relation between the alignment marks 22A

and 22B (see Fig.1) and corresponding predetermined reference marks (not shown) is measured by the RA microscopes 19A and 19B, and results of the measurement are supplied to the main control system 16. The main control system 16 aligns the master mask MR based on the measurement results.

The substrate R1 is absorbed and held on a substrate holder (not shown), the substrate holder is fixed on a Z-tilt state 8, and the Z-tilt stage 8 is placed on an XY stage 9 such that the Z-tilt stage 8 can move two-dimensionally. The XY stage 9 positions the Z-tilt stage 8 in the X, Y and rotational directions by a linear motor for example. An X coordinate, a Y coordinate and a rotation angle of the Z-tilt stage 8 are measured by a moving mirror 10 fixed on an upper end of the Z-tilt stage 8 and by the a laser interferometer 11. These measured values are supplied to the main control system 16 and a substrate stage driving system 12. The substrate stage driving system 12 controls the operation of the XY stage 9 based on the measured values and control information from the main control system 16.

A driving mechanism is incorporated in the Z-tilt stage 8 for controlling a focus position (position in a direction of an optical axis AX) and an inclination angle of the substrate R1. The focus positions are measured at a plurality of measuring points on a surface of the substrate R1 by

auto-focus sensor (not shown). Based on the measured results, the Z-tilt stage 8 adjusts the focus of the surface of the substrate R1 with an image plane of the projection optical system 6 in an auto-focus manner or auto-leveling manner. At that time, it is also possible to defocus the surface of the substrate R1 by a predetermined amount. The Z-tilt stage 8 and the XY stage 9 constitute the substrate stage. Further, a plurality of reference marks (not shown) for alignment are formed on the Z-tilt state 8, and an alignment sensor for alignment is disposed on a side surface of the projection optical system PL.

It is also possible to expose a reduced image of the parent pattern of the master mask MR or other master reticle while stitching screens. In this case, the master reticle is exchanged by another reticle using a reticle loader (not shown) provided in the vicinity of the reticle stage 13. The reticle stage 13 may be constructed such that a plurality of master reticles can be placed on the reticle stage 13. On the master reticle transferred onto the reticle stage 13, kinds of parent pattern, conditions such as illumination conditions and image-forming conditions are recorded in the form of bar codes BC. The main control system 16 reads the bar codes BC through a bar code reader 17, and recognizes these conditions. Information such as illumination conditions

corresponding to the conditions read from the bar code BC is stored as a table in a memory in the main control system 16. Information such as the appropriate exposure amount with respect to the photoresists on the substrates R1 and R2 and the like is also stored in the memory in the main control system 16. Based on the information, the illumination conditions (σ value and the like) with respect to that master mask MR, the resolution and the exposure amount are set.

~~In the projection exposure~~ apparatus shown Fig.3, although the fly-eye lens is used as the optical integrator (homogenizer) 3, a rod integrator may be be used instead thereof. The projection optical system PL may any of refractive system, reflection system and catadioptric system. As the catadioptric projection optical system, it is possible to use an optical system in which a plurality of refractive optical elements and two reflection optical elements (at least one of them is a concave mirror) are disposed on a straightly extending optical axis without bending as disclosed in USP No.5788229. As the illumination light for exposure, a single wavelength laser in an infrared region or visible region lased from a DFB semiconductor laser or fiber laser may be amplified with a fiber amplifier doped with erbium (Er) (or both erbium and ytterbium (Yb)), and a harmonic whose wavelength is converted into ultraviolet rays using a non-linear optical

crystal may be used.

For example, if the lasing wavelength of the signal wavelength laser is in a range of 1.51 to 1.59 μm, an eighth order harmonic having generated wavelength in a range of 189 to 199 nm, or a tenth order harmonic having generated wavelength in a range of 151 to 159 nm is output. Especially when the lasing wavelength is in a range of 1.544 to 1.553 μm, an eighth order harmonic in a range of 193 to 194 nm, i.e., ultraviolet rays having substantially the same wavelength as that of the ArF excimer laser can be obtained. If the lasing wavelength is set in a range of 1.57 to 1.58 μm, a tenth order harmonic in a range of 157 to 158 nm, i.e., ultraviolet rays having substantially the same wavelength as that of the F_2 excimer laser can be obtained.

Further, when the lasing wavelength is in a range of 1.03 to 1.12 μm, a seventh order harmonic having generated wavelength in a range of 147 to 160 nm is output, and especially when the lasing wavelength is in a range of 1.099 to 1.106 μm, a seventh order harmonic having the generated wavelength in a range of 157 to 158 nm, i.e., ultraviolet rays having substantially the same wavelength as that of the F_2 excimer laser can be obtained. As a single wavelength lasing laser, an ytterbium doped fiber laser is used.

As the illumination light for exposure, it is possible

to use light in soft X-ray region (wavelength of about 5 to 50 nm) generated from a laser plasma light source or an SOR (Synchrotoron Orbital Radiation) ring, for example, EUV (Extreme Ultraviolet) light having a wavelength of 13.4 nm or 11.5 nm can also be used. In the EUV exposure apparatus, the reduction projection optical system is a reflection system only comprising a plurality of (e.g., about 3 to 6) reflection optical elements. As a master reticle on which the parent pattern is formed, a reflection reticle is used.

Next, one example of entire operation when the phase-shift reticle and the correction exposure reticle are produced using the projection optical system shown in Fig.3 and the semiconductor device is produced using these reticles will be explained with reference to Figs.4 and 5. The operation for transferring patterns of a plurality of master reticles while stitching screens will be explained below.

[First Step]

Fig.4 is an explanatory view of steps for producing a master reticle from a circuit pattern of a predetermined layer of a semiconductor device. In Fig.4, the circuit pattern 30 is designed. Next, a parent pattern 31 is formed on an image memory of a computer by enlarging the circuit pattern 30 $\alpha \cdot \beta$ times. The parent pattern 31 is divided vertically and horizontally on the image memory to generate N-number (N=16

in Fig.4) of partial patterns 32-1, 32-2, ..., 32-N. The partial parent patterns 32-1 to 32-N are drawn on light-transmission substrates respectively using an electron beam drawing apparatus, thereby producing N-number of master reticles MRi (i=1 to N). At that time, each master reticle MRi is formed with the alignment marks 22A and 22B.

Further, a portion of the parent pattern 31 on the image memory corresponding to the phase shifter is formed as a transmission pattern 35, thereby forming a parent pattern 33 for the phase shifter. The parent pattern 33 is vertically and horizontally divided to generate N-number of partial patterns 34-1, 34-4, ..., 34-N. Similarly, these partial parent patterns are drawn on corresponding substrates using the electron beam drawing apparatus to produce N-number of phase shifter master reticles MPi (i=1 to N). At that time also, each master reticle MPi is formed with alignment marks 36A and 36B.

When the parent patterns 31 and 33 are divided into a plurality of partial parent patterns, a pattern (connected portion) may exist or may not exist on the boundary between the partial patterns. As explained above, a joint portion having a shape corresponding to that of the pattern may be formed so that the pattern (connected portion) does not exist on the boundary as minimum as possible and the pattern is not

divided through bumps and dips.

It is unnecessary to form all of the divided partial parent patterns on different master reticles, and some partial parent patterns may be formed on the same master reticle. In this case, a desired partial parent pattern may be selected from the plurality of partial parent patterns formed on the one master reticle and may be transferred onto a working reticle substrate.

When the parent patterns 31 and 33 are divided into the plurality of partial parent patterns, the area of the parent patterns 31 and 33 may be divided equally, but it is preferable to divide the mask pattern into unit circuit patterns each having a specific function, e.g., into IP (Intellectual Property) portions constituting the system LSI. That is, it is preferable to form unit circuit patterns such as a CPU core portion, a RAM portion, a ROM portion, an A/D converter, and a D/A converter on different master reticles, respectively. In this case, when working reticles for different kinds of system LSIs are produced, the same master reticles can be used for a common IP portion, and the number of master reticles to be produced can be reduced. Therefore, the producing cost of the working reticles, and by extension the producing cost of the system LSIs can be reduced.

[Second Step]

Fig.5 is an explanatory view of steps for producing the semiconductor device using the above master reticle. In Fig.5, first, the phase-shift reticle WR1 is produced using the projection exposure apparatus shown in Fig.3. That is, the light shield film is formed on the substrate R1 and a photoresist is applied on the film. Then, the substrate R1 is loaded onto the Z-tilt stage 8. Next, a first master reticle MR for the light shield pattern is loaded onto the reticle stage 13 shown in Fig.3, alignment is carried out using the RA microscopes 19A and 19B and then, the first shot region of the substrate R1 is moved to an exposure region of the projection optical system PL by driving the XY stage 9. The reticle blind (not shown) in the condenser lens system 5 is adjusted so that only a desired pattern on the master mask MR1 on the master reticle MR1 is illuminated, the exposure light IL illuminates the master mask MR1, and a reduced image 32-1P of the illuminated partial parent pattern 32-1 is exposed on the substrate R1 through the projection optical system PL. The resolution of the projection optical system PL at that time is set such that an image of a light shield pattern having narrowest line width is sufficiently projected, and the exposure amount is set to the appropriate exposure amount.

B23 Subsequently, when an image of a pattern in a different

region on the master mask MR1 is transferred to a different shot region of the substrate R1, the reticle blind is adjusted again so that the pattern in the different region is illuminated, the Z-tilt stage 8 is moved in a step manner to move a next shot region on the substrate R1 to the exposure region of the projection optical system PL, and the shot region is illuminated with the exposure light IL while stitch screens. In this example, however, in order to expose the reduced image 32-2P of the pattern of the master reticle MR2, the master reticle is exchanged on the reticle stage 13 and then, step move of the Z-tilt stage 8 (substrate R1) is carried out, and the pattern is exposed while stitching screens. The operation for exposing the reduced images of the corresponding master reticles in the N-number of shot regions on the substrate R1 is repeated in a step-and-repeat manner (step-and-stitch manner), and the N-number of $1/\alpha$ times reduced images 32-1P to 32-NP of the partial parent patterns are transferred onto the substrate R1. Thereafter, steps such as development of the photoresist, etching of the light shield film and removal of the resist are carried out, and the substrate R1 is formed with the light shield patterns such as the ~~light shield~~ patterns PA2 ~~to PC2 shown in Fig. 1~~(B).

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Next, a photoresist is applied on the substrate R1, and the substrate is again loaded onto the Z-tilt stage 8 of the

projection exposure apparatus. Then, the N-number of 1/α times reduced images 34-1P to 34-NP of the partial parent patterns of the phase shifter master reticles MP1 to MPN shown in Fig.5 are exposed on the N-number of shot regions on the substrate R1 while stitching screens. Thereafter, development, etching of the substrate R1 itself and the resist removing operation are carried out, thereby completing the phase-shift reticle WR1 having the phase shifter shown in Fig.1(C).

[Third Step]

Next, the correction exposure reticle WR2 is produced using the projection exposure apparatus shown in Fig.3. The light shield file is formed on the substrate R2, and a photoresist is applied on the film. Then, the substrate R2 is loaded onto the Z-tilt stage 8 shown in Fig.3. Next, a first master reticle MR for the light shield pattern is loaded onto the reticle stage 13, alignment is carried out using the RA microscopes 19A and 19B and then, the first shot region of the substrate R2 is moved to an exposure region of the projection optical system PL by driving the XY stage 9. The exposure light IL illuminates the master mask MR1, and a reduced image 32-1P of the illuminated partial parent pattern 32-1 is projected and exposed on the substrate R2 through the projection optical system PL. The resolution of the

projection optical system PL at that time is set to the same value as that when the phase-shift reticle WR1 is produced, but the exposure amount is set to about half of the appropriate exposure amount. The exposure amount may be set to the appropriate exposure amount, and the variable aperture stop 7 in the projection optical system PL may be controlled to reduce the numerical aperture NA of the projection optical system PL to lower the resolution. Alternatively, the Z-tilt stage 8 may be driven to defocus the surface of the substrate R2 and the substrate R2 may be exposed.

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Similarly, 1/α times reduced images 32-2P to 32-NP of the partial parent patterns of the master reticles MR2 to MRN are transferred onto the substrate R2 while stitching screens. Then, development of the photoresist, etching of the light shield film and the resist removing operation are carried out, thereby producing the correction exposure reticle WR2 as shown in Fig.1(D).

Sub B26

In the above embodiment, the parent pattern 31 is divided into the N-number of square partial patterns 32-1 to 32-N having the same size as shown in Fig.4. However, when the reduced images of these partial parent patterns are actually exposed while stitching screens, if no pattern is astride the boundary, the influence of joint error is reduced. Thereupon, as disclosed in Japanese Patent Application

~~Laid-open No.9-190962 for example, when the parent pattern 31 (the same is applied to the phase-shift parent pattern 33) is divided, the boundary between the adjacent partial parent patterns may be formed with bumps and dips so that patterns (especially patterns having narrow line width) do not exist as minimum as possible. By transferring the reduced images of such a plurality of divided partial parent patterns having different shapes while stitching screens, it is possible to largely reduce the number of joint portions (pattern astride two short regions) on the substrate. Therefore, it is possible to enhance the production precision of the phase-shift reticle WR1 and the correction exposure reticle WR2 as the working reticles.~~

[Fourth Step]

In this step, a predetermined circuit pattern is formed in each shot region on the wafer W using the phase-shift reticle WR1 and the correction exposure reticle WR2 shown in Fig.5. At that time, using a semiconductor device producing-projection exposure apparatus having substantially the same structure as that of the projection exposure apparatus shown in Fig.3 and having the projection magnification of $1/\beta$, a wafer W on which a photoresist is applied is loaded onto a wafer stage of this projection exposure apparatus. Then, the phase-shift reticle WR1 is

loaded onto the reticle stage of this projection exposure apparatus, and positioning of the reticle is carried out using the alignment marks 23A and 23B. Thereafter, 1/β times reduced image 38 of the light shield pattern of the phase-shift reticle WR1 is exposed on each shot region on the wafer W.

Thereafter, the phase-shift reticle WR1 is replaced by the correction exposure reticle WR2, positioning of the reticle is carried out using the alignment marks 2$A and 24B and then, 1/β times reduced image 39 of the light shield pattern of the correction exposure reticle WR2 is exposed in a superimposing manner on each shot region on the wafer W. Next, development of the wafer W and etching are carried out, and a predetermined circuit pattern is formed on each shot region of the wafer W. The same pattern forming step is repeated a plurality of times, and dicing, bonding and packaging steps are carried out, thereby producing the semiconductor device of this example.

As described above, in this example, the phase-shift reticle WR1 and the correction exposure reticle WR2 are produced using the same master reticles and the same optical projection exposure apparatuses shown in Fig.3. In this case, a superimposing error between the two reticles WR1 and WR2 due to drawing positional deviation of the parent pattern of the master reticle or due to distortion difference between

the optical projection exposure apparatuses is not generated at all. Therefore, there is a merit that superimposing exposure of the phase-shift reticle WR1 and the correction exposure reticle WR2 can be carried out with high superimposing precision.

In this example, the line width of the light shield pattern on the correction exposure reticle WR2 is thicker than the line width of the light shield pattern of the phase-shift reticle WR1. This is because that an image formed by the correction exposure reticle WR2 is not sufficiently sharp (dark) as compared with an image formed by the phase-shift reticle WR1, and there is an adverse possibility that the sharp image formed by the phase-shift reticle WR1 may be deteriorated.

Therefore, when the resolution performance (γ characteristic) of the photoresist applied on the wafer is extremely high, since an influence of the image formed by the correction exposure reticle WR2 on the image formed by the phase-shift reticle WR1 is reduced, the line width of the light shield pattern of the correction exposure reticle WR2 may coincide with the line width of the light shield pattern of the phase-shift reticle WR1.

It is also possible to sufficiently darken the image formed by the correction exposure reticle WR2 relatively, by

setting the exposure amount when the pattern of the correction exposure reticle WR2 is transferred less than about half of the above-described appropriate exposure amount as compared with the exposure amount when the pattern of the phase-shift reticle WR1 is transferred.

When an electronic device is actually produced, such an exposure step is repeated 20 times or more, but the phase-shift reticle and the correction exposure reticle of this example may be used only in the exposure step for transferring a fine pattern having extremely thin line width such as a gate forming step.

In a device producing-projection exposure apparatus using DUV rays (far ultraviolet rays) or VUV rays (vacuum ultraviolet rays), a transmission reticle is generally used as the working reticle. Therefore, as material for the substrate R1 and R2 for the working reticle (reticles WR1 and WR2), silica glass, silica glass doped with fluorine, fluorite, magnesium fluoride, quartz crystal or the like is used. Further, when the device producing-projection exposure apparatus is an EUV exposure apparatus using EUV rays as the exposure light, a reflection mask is used as the working reticle, and a transmission mask (stencil mask, membrane mask) is used in a mask projection type electron beam exposure apparatus. As the substrates R1 and R2 for the working

reticle for these exposure apparatus, silicon wafer or the like is used.

The illumination optical system constituted by a plurality of optical elements and the projection optical system are assembled into the projection exposure apparatus and optical adjustment is carried out, and further the reticle stage and the wafer stage each comprising a large number of mechanical parts are mounted to the projection exposure apparatus body, wires and tubes are connected, and all of them are totally adjusted (electrical adjustment, confirmation of operation and the like), thereby producing the projection exposure apparatus of the above-mentioned embodiment. It is preferable to produce the projection exposure apparatus in a clean room where a temperature and a clean degree are managed.

The present invention is not limited to the above-mentioned embodiments, and the invention may, as a matter of course, be embodied in various forms without departing from the gist of the present invention. Furthermore, the entire disclosure of Japanese Patent Application 10-369929 filed on December 25, 1998 including description, claims, drawings and abstract are incorporated herein by reference in its entirety.

Industrial Applicability

According to the first producing method of a mask according to the present invention, as compared with a case in which two kinds of patterns for a phase-shift mask and a correction exposure mask are designed and each of the patterns is drawn by an electron beam drawing apparatus or the like, it is only necessary to design the patterns and draw the patterns by the electron beam drawing apparatus or the like only when the master mask is formed. Therefore, the phase-shift mask and the correction exposure mask can be produced within a short time at low cost.

Further, when the phase-shift mask and the correction exposure mask are produced by transferring the reduced image of the master mask onto the substrate using an optical projection exposure apparatus, since the influence of the drawing error of the electron beam drawing apparatus or the like is reduced, there is a merit that precision of pattern of the two masks can be enhanced.

Further, according to the second producing method of a mask, it is possible to produce the correction exposure mask within a short time and at low cost.

Next, according to the mask producing apparatus of the present invention, it is possible to carry out the mask producing methods of the present invention. Further, according to the first and second device producing methods

of the present invention, since it is possible to produce the phase-shift mask and the correction exposure mask within a short time, a time required for producing the device can be shortened, and a device can be produced at low cost.

Further, according to the first and second masks of the invention, there is a merit that the phase-shift mask and the correction exposure mask thereof can be obtained within a short time at low cost.